REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE

3. REPORT TYPE AND DATES COVERED
FINAL/15 OCT 93 TO 14 OCT 94

4. TITLE AND SUBTITLE
SPECTRUM ALLOCATION STRATEGIES FOR COMMUNICATION NETWORKS

5. FUNDING NUMBERS
2304/DS
F49620-94-1-0005

6. AUTHOR(S)
ROBERT J. MCELIECE

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
CALIFORNIA INSTITUTE OF TECHNOLGOY
DEPARTMENT OF ELECTRICAL TECHNOLOGY
PASADENA, CA 91125

8. PERFORMING ORGANIZATION REPORT NUMBER
AFOSR-TR- 95 - 0388

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AFOSR/NM
110 DUNCAN AVE, SUTE B115
BOLLING AFB DC 20332-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
F49620-95-1-0005

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
APPROVED FOR PUBLIC RELEASE: DISTRIBUTION IS UNLIMITED

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Models of multi-user comunications systems have been developed and studied. The limits for such systems have been computed by linear programming.

19950614 049

14. SUBJECT TERMS

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR(SAME AS REPORT)

Final Technical Report, October 1, 1993–September 30, 1994

SPECTRUM ALLOCATION STRATEGIES FOR COMMUNICATION NETWORKS
(AFOSR Grant F49620-94-1-0005)

Robert J. McEliece
Department of Electrical Engineering
California Institute of Technology
Pasadena, CA 91125

The long-term goal of this project has been to obtain a basic mathematical understanding of the problems associated with communication in the presence of severe noise, e.g., fading, jamming or interference from other (friendly) signals. Our basic approach has always been to apply the techniques and insights of *information theory* to these problems. In the period covered by this report, we continued, and greatly extended, our study of models for *multi-user* communication systems, i.e., systems in which many simultaneous two-way conversations must share a common band of frequencies. We have shown (refs. [4],[5],[6],[7],[9]) that the ultimate limits for such systems (measured by the number of conversations per unit of available bandwidth) can, in some cases, be computed by a fairly simple linear program. Later, we extended this work (ref. [16]) to show that it applies to the more general class of *blocking service networks*, i.e, networks which provide many kinds of service to many customers simultaneously. Besides "cellular" communication networks, we have already shown that our new theory also applied to ordinary telephone networks, and to stochastic "bin packing" TDMA communication networks. Most recently, we studied the performance of a class of practical bandwidth allocation algorithms, the "distributed dynamic" algorithms, and showed (ref. [21]) that in many cases they are nearly optimal.

In the past year, we continued, to explore this extremely fertile research area. Our most important result was a proof that the distributed dynamic algorithms referred to above are asymptotically optimal in a very strong sense, viz., for any value of the (normalized) offered traffic, as the number of channels becomes large, the carried traffic for these algorithms equals or exceed that of any other algorithm (ref. [25]). We also found a class of modified algorithms which are a bit more complex, but which achieve optimality "faster" than the timid algorithm (refs. [23] and [24].)

AFOSR-sponsored publications Since 1191.
(entries marked "•" are in refereed, archival journals.

1. •"Performance of Binary Block Codes at Low Signal-to-Noise Ratios" (with C.-C. Chao, Eugene Rodemich, and Laif Swanson), *IEEE Trans. Inform. Theory* vol. IT-38 (1992) pp. 1677–1687.

2. "Some Properties of Memoryless Multiterminal Interference Channels," (with M. Mandell), Proc. 1991 International Symposium on Information Theory, p. 212.

3. "Dynamic Channel Assignment in Cellular Radio" (with Kumar Sivarajan and John Ketchum), Proc. 1990 IEEE Vehicular Technology Conference, pp. 631–637.

4. "Performance Limits for FDMA Cellular Telephone Systems" (with Kumar Sivarajan), Proc. 1990 Allerton Conference on Communication, Control, and Computing, pp. 869–880.

5. "Performance Limits for Cellular Telephone Systems Defined by Hypergraphs," (with. Kumar Sivarajan), Proc. Third IEE Conf. Telecommunications (Edinburgh, March 1991), pp. 360–365

6. "Performance Limits for Cellular Multiuser Communications Systems," (with K. Sivarajan), proc. Proc. 1991 International Symposium on Information Theory, p. 212.

7. "Asymptotic Performance of Fixed and Dynamic Channel Assignments in Cellular Radio," (with. Kumar Sivarajan), Proc. 1991 International Symposium on Information Theory, p. 154.

8. "Some Properties of Memoryless Multiterminal Interference Channels," (with M. Mandel), Proc. 1991 International Symposium on Information Theory, p. 212.

9. •"Performance Limits for Channelized Cellular Telephone Systems", (with Kumar Sivarajan) accepted in Oct. 1992 for publication in *IEEE Trans. Inform. Theory*.

10. "The Extended Invariant Factor Algorithm with Application to the Forney Analysis of Convolutional Codes" (with Ivan Onyszchuk), Proc. *1993 Int. Symp. Inform. Theory*, p. 142.

11. •"Some VLSI Decompositions of the deBruijn Graph," with S. Dolinar and T.-M. Ko, *Discrete Mathematics 106/107 (1992)*, pp. 189–198.

12. "VLSI Decompositions for deBruijn Graphs," (with Sam Dolinar and Tsz-Mei Ko), Proc. 1992 IEEE International Symposium on Circuits and Systems, pp. 1855–1858

13. "Maximal Codeword Lengths in Huffman codes," (with Y. S. Abu-Mostafa), to appear in the proceedings of "GolombFest 60" (a symposium held to celebrate the 60th birthday of Professor Solomom W. Golomb, May 29–31, 1992.)

14. "A Comparison of CDMA and Frequency Hopping in a Cellular Environment," (with M. Mandell), Proc. First International Conference on Universal Personal Communications (UPC '92). Dallas: Sept. 29–Oct. 2, 1992, pp. 07.01.1–07.01.5

15. "Heavy Traffic Performance of a Class of Channel Assignment Algorithms," (with K. Sivarajan), Proc. Third International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC '92). Boston: October 19–21, 1992, pp. 550–555. (Also published as IBM Research Report RC 18212 (79916).)

16. "Maximizing Marginal Revenue In Generalized Blocking Service Networks," (with K. Sivarajan), Proc. 1992 Allerton Conference on Communication, Control, and Computing, pp. 455–464.

17. "A Comparison of CDMA and Frequency Hopping in a Cellular Environment," (with M. Mandell). Proc. *1993 Int. Symp. Inform. Theory*, p. 252.

18. *A Comparison of CDMA and Frequency Hopping in a Cellular Environment*, by Michael I. Mandell. Caltech Ph.D. thesis. November 25, 1992.

19. •"Phased Burst Error Correcting Array Codes," (with R. Goodman and M. Sayano), *IEEE Trans. Inform. Theory* IT-39 (March 1993), pp. 684–693.

20. "Comparison of the Capacities of CDMA, FH, and FDMA Cellular Systems," (with M. Izumi and M. Mandell), proc. *Wireless 93* (The Fifth Annual International Conference on Wireless Communications), Calgary Canada, July 1993, pp. .

21. "Why Channel Assignment Algorithms are Asymptotically Smart," with E. R. Rodemich and S. K. Deora. 1993 Allerton Conference on Communication, Control, and Computing, September 1993, pp. 207–216.

22. "Performance Limits for Resource Allocation Algorithms," (with K. Sivarajan), special issue of *IEEE J. Sel. Areas in Commun.*, "Advances in the Fundamentals of Networking," to appear.

23. "Asymptotic Performance Analysis of a Timid DCA Algorithm" (with S. K. Deora), Proc. Conf. Inform. Sciences and Systems (Baltimore, Maryland), March 1995.

24. "Performance Limits for Blocking Multiuser Communication Networks," (with S. K. Deora), Proc. 1995 Information Theory Workshop on Multiaccess and Queuing

25. "Performance of Channel Assignment Algorithms for Cellular Telephony," Caltech Ph.D. thesis by S. K. Deora, May 1995.